Telescope Fiducial System

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Controls & Interlocks Operational Readiness Review

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July 14, 1999

Fiducial System
Requirements and Specifications

Altitude: 7.2 microns RMS (±18 microns at transducer radius)
Azimuth: 7.2 microns RMS (± 18 microns at transducer radius)
Rotator: 30 microns RMS (± ?? microns at transducer radius)

Basis: Requirements derived from pointing precision requirements.

Reference: Telescope Requirements Document, Section 4.5

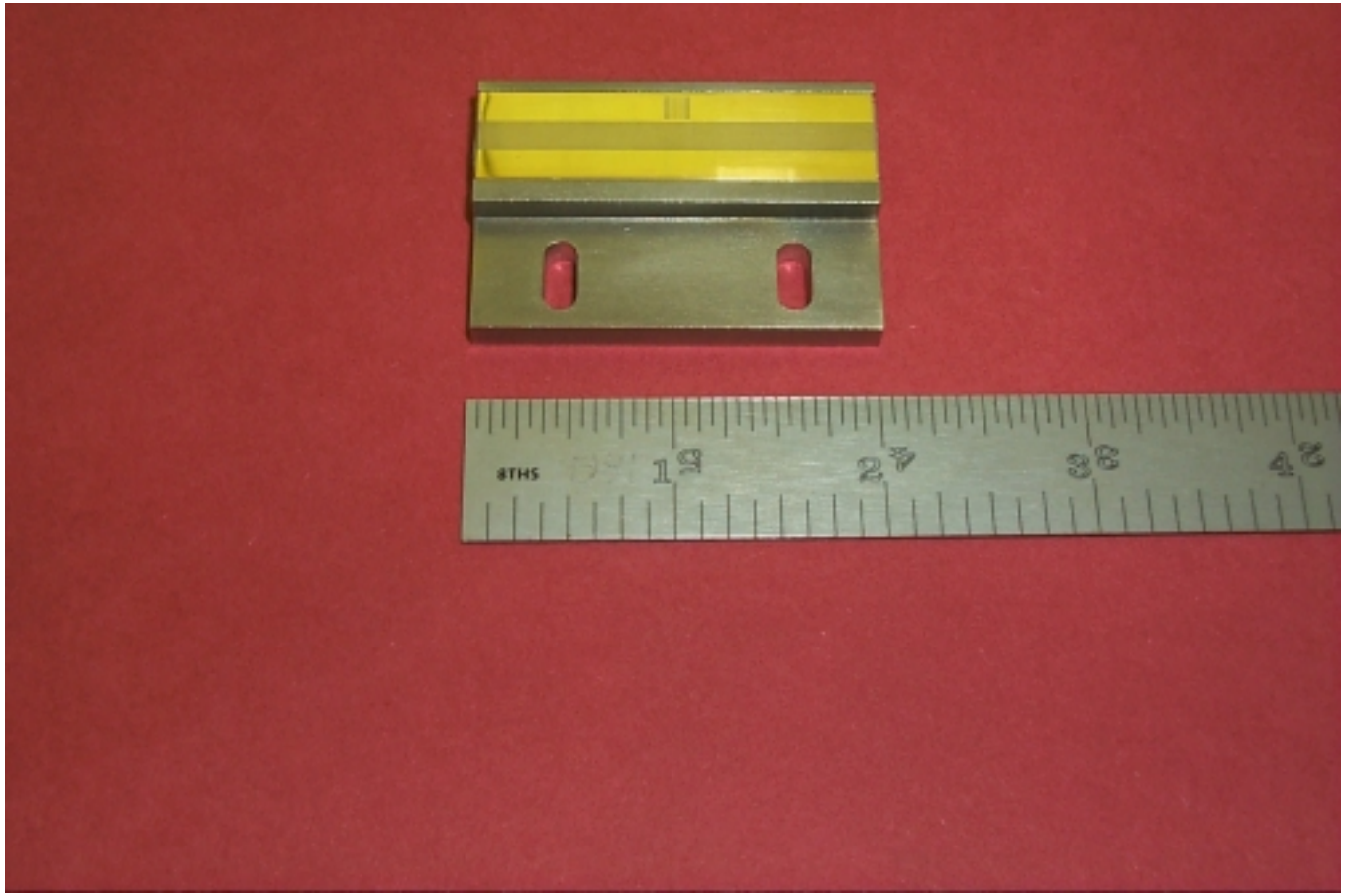
Mode of Operation

- At each fiducial crossing, a TTL pulse is generated and fed into the Motion Control Processor (MCP) and the MEI controller card.
- Fiducial pulse serves as an interrupt that causes the system to “latch” the incremental encoder value at that point.
- MEI only has one interrupt port, so all encoder inputs are latched at once. MCP keeps track of which axis generated the interrupt.
- Home-grown board feeds the single interrupt into both processors.

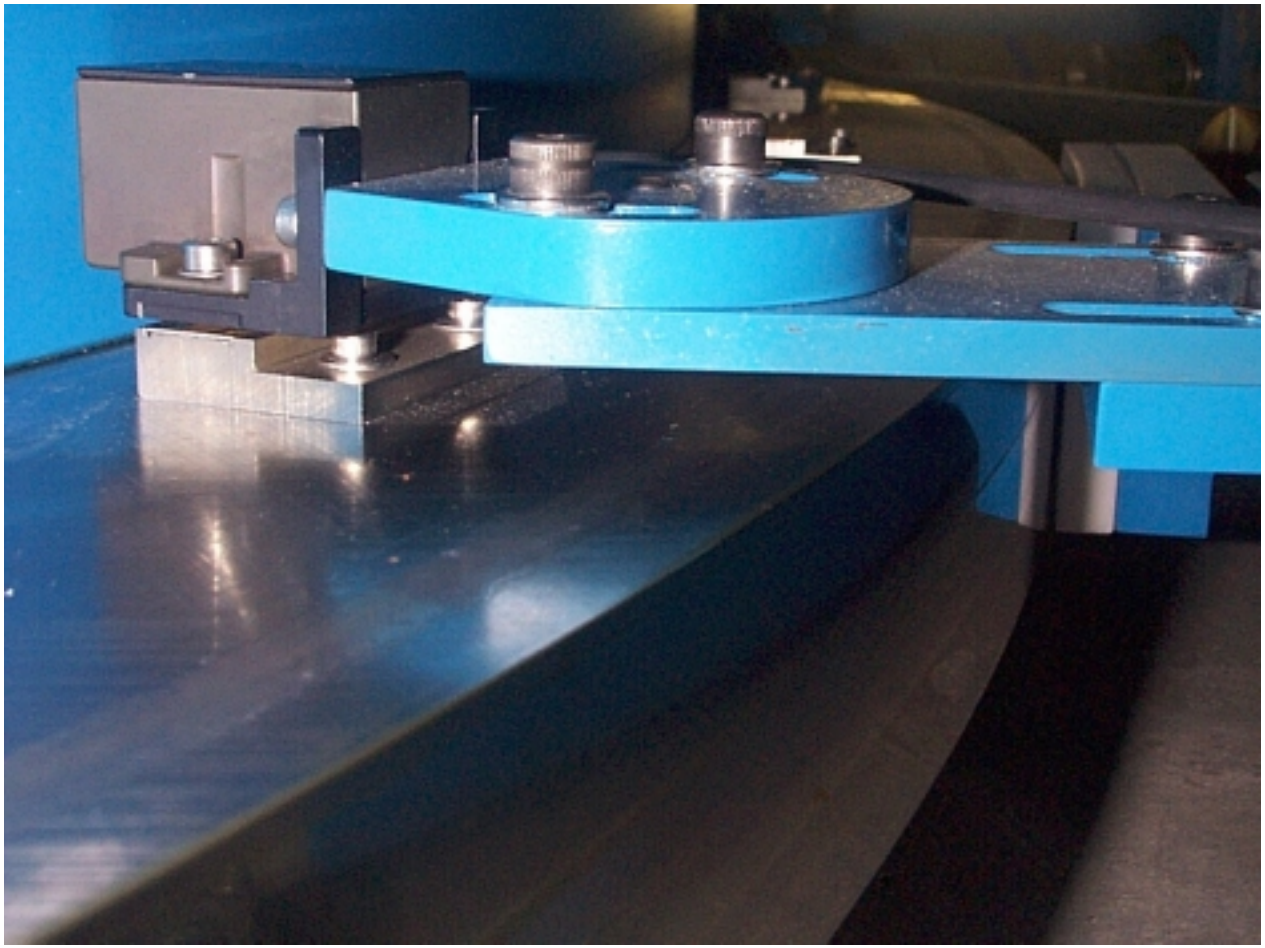
Implementation Method

- Azimuth and Altitude
  - Heidenhain Optical Tape Encoder System
    - LIDA 18C scanner heads (one per axis)
    - IBV 600 interpolator (1Vp-p input, gain = 1, TTL output)
    - LIDA steel scale tape with reference marks at 50mm intervals
      - 50mm long tape sections are mounted on precisely-made stainless steel blocks
  - Tape blocks positioned at 15-degree intervals
    - 24 locations on the azimuth axis (360 degrees)
    - 7 locations on the altitude axis (0-90 degrees)

Azimuth Fiducial Tape Block

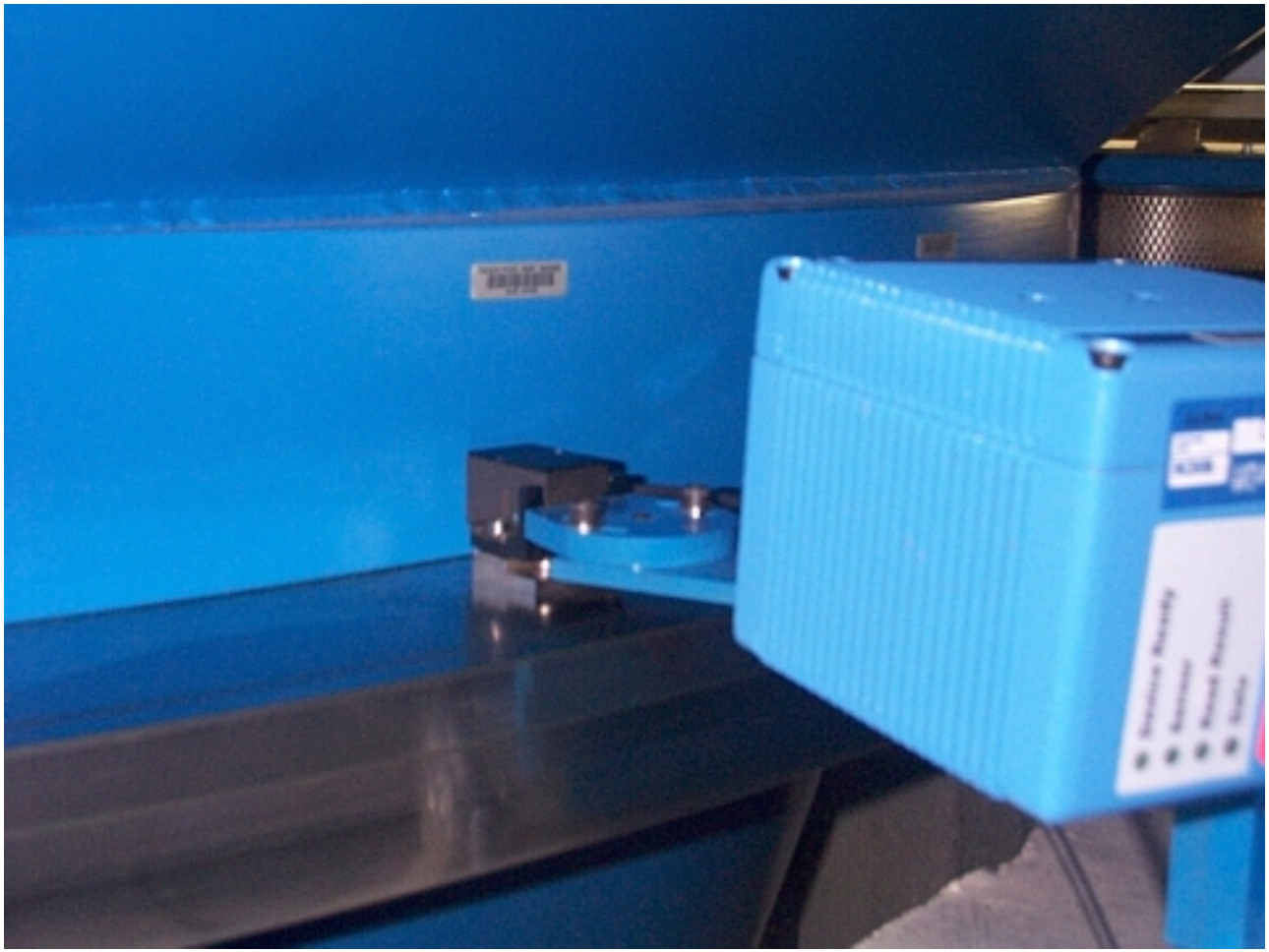


Azimuth Fiducial System

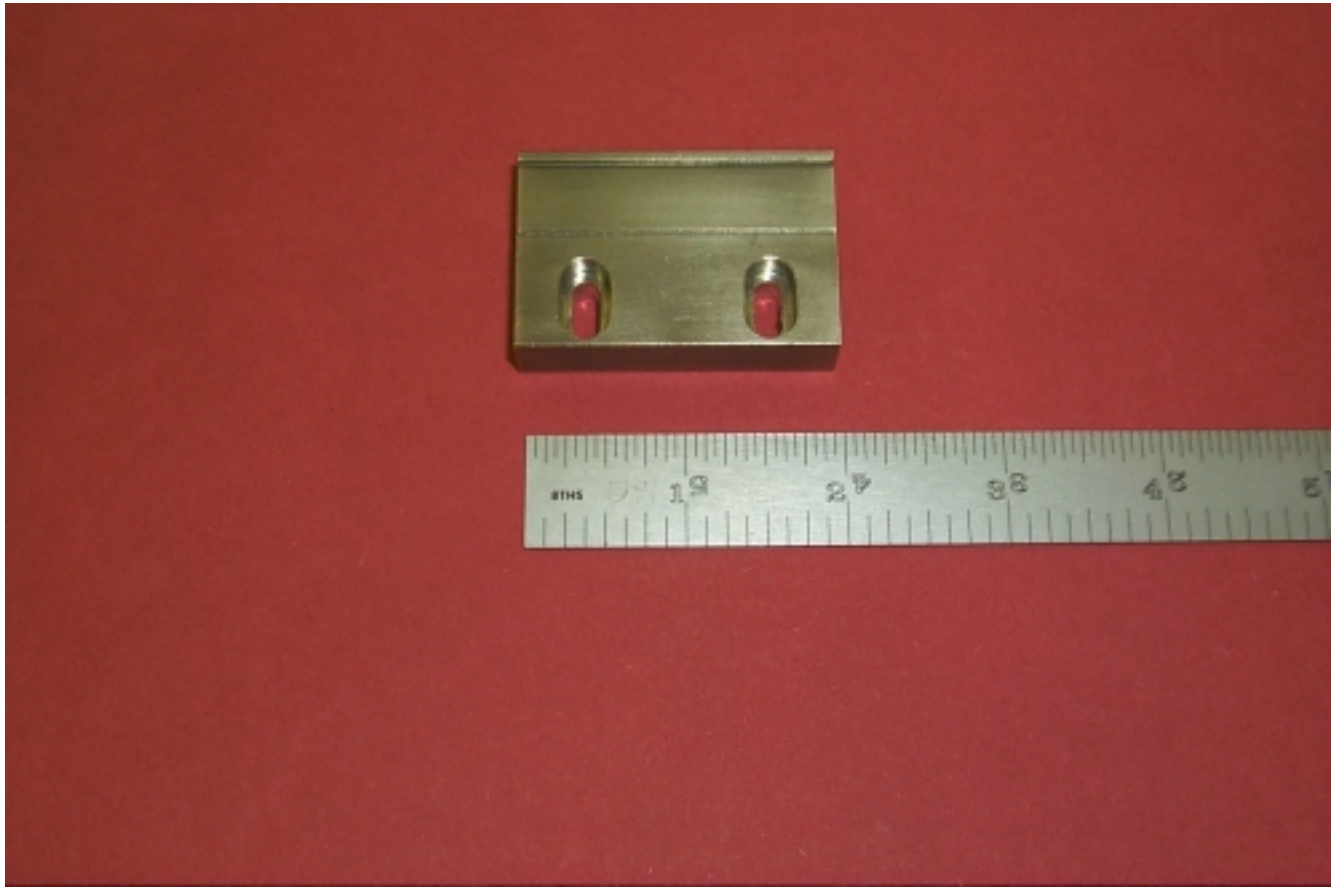


Sloan Digital Sky Survey

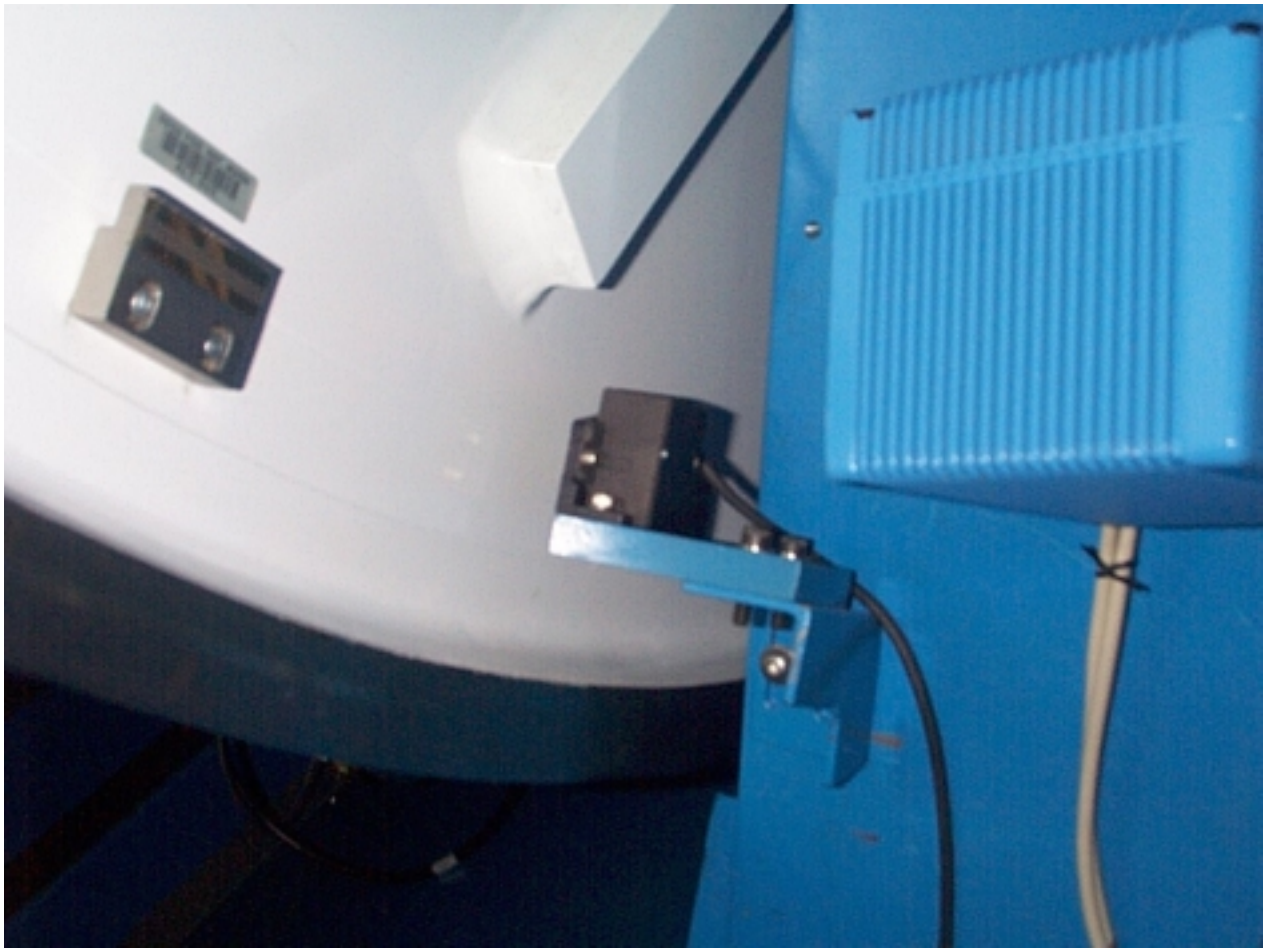
Azimuth Fiducial Barcode System



Altitude Fiducial Tape Block



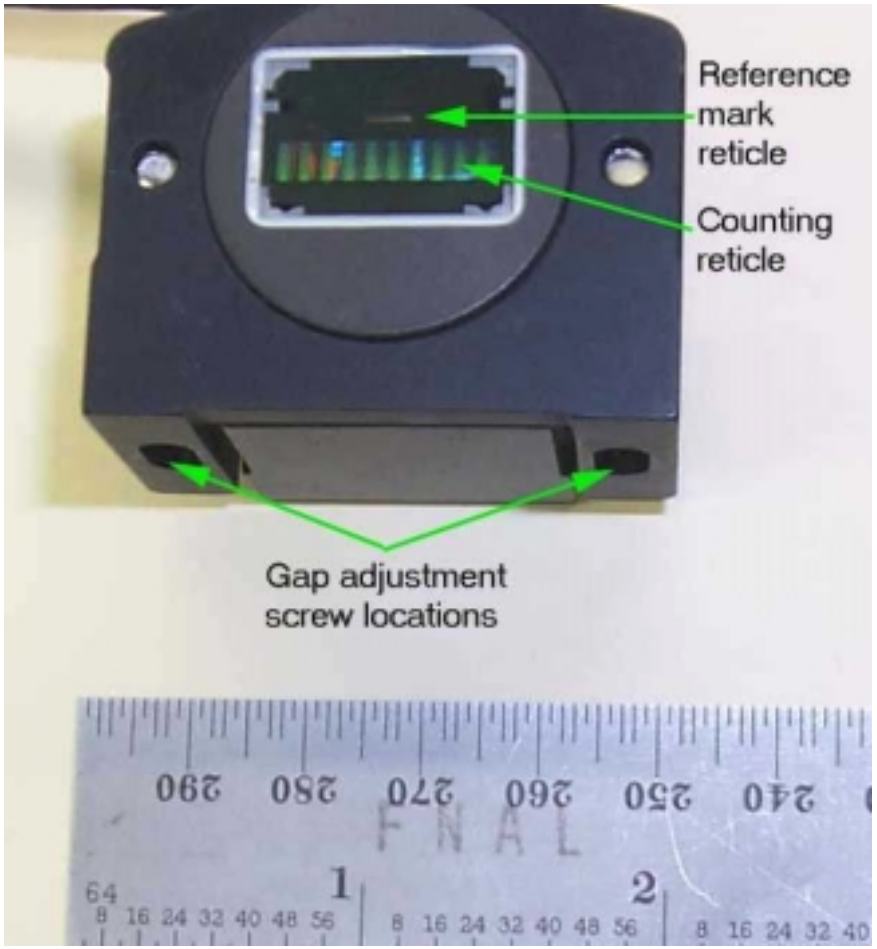
Altitude Fiducial System



Implementation Method

- Rotator
  - Heidenhain Optical Tape Encoder System
    - ERA 880C scanner heads (three for servo loop, one for fiducial)
    - IBV 660 interpolator (1Vp-p input, gain = 400, TTL output)
    - Continuous LIDA steel scale tape with uniquely-spaced reference marks at approximately 40mm intervals
    - Must cross two sets of reference marks to obtain absolute position on tape.

Rotator
Encoder
Head



Status of Implementation

- Fiducial systems are functional on all three axes
- One fiducial on each axis has been in use over the past four months to "zero" the axis coordinate system.
- Some system tests have been done to verify the performance of all fiducials. Results will be discussed in subsequent slides.
- More testing, over time and under different velocities and temperatures, must be done to quantify overall system performance.

Fiducial Performance - Azimuth

- Insert azimuth fiducial graphs here…

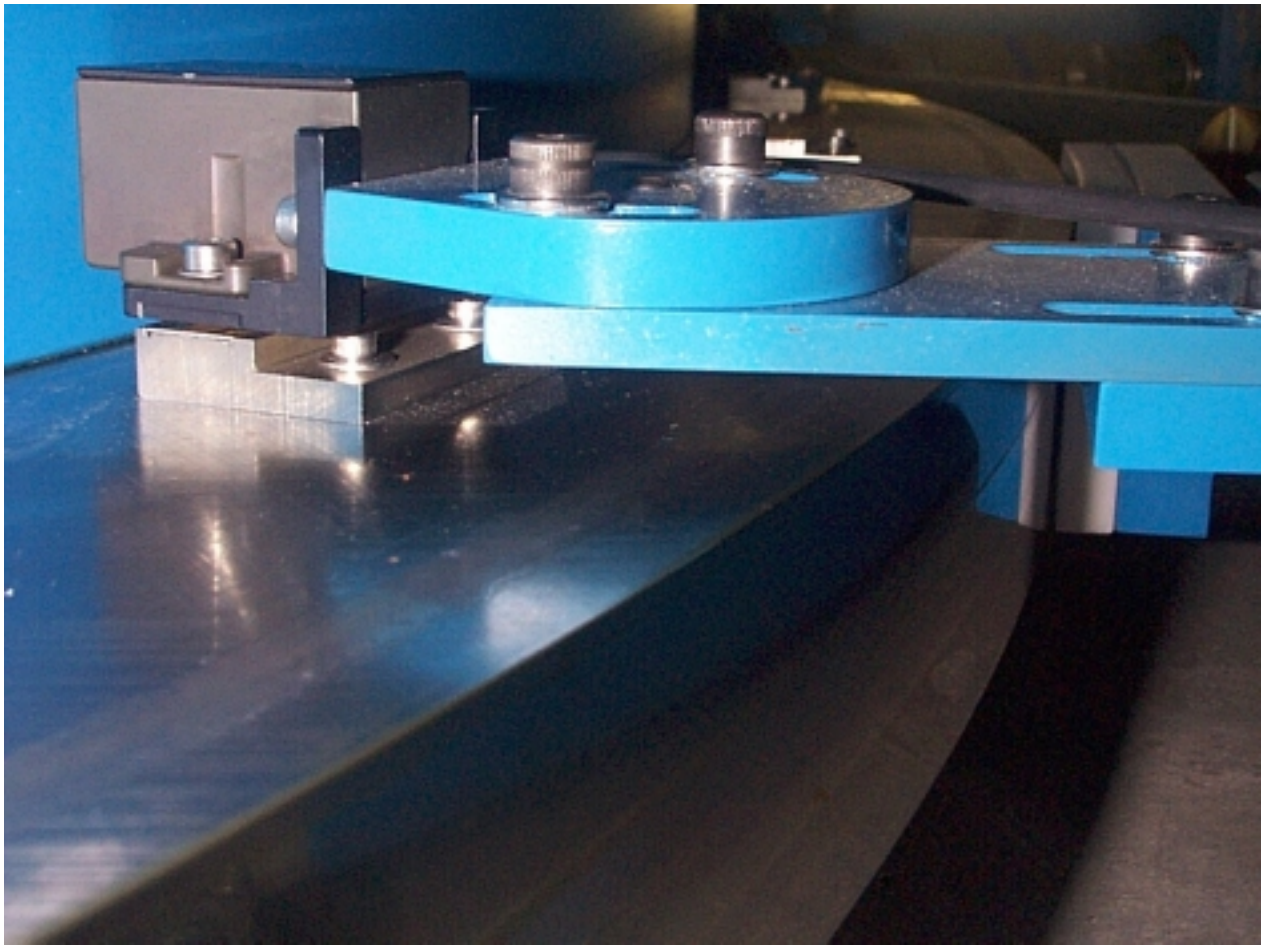
Fiducial Performance - Azimuth

- Individual fiducial repeatability at low velocities (tracking rates) is very good.
  - At velocities of 288 asec/sec (20,000 cts/sec), worst-case repeatability spread in March tests was 44 encoder counts.
  - At the drive disk radius, 44 encoder counts equates to 3.9 microns.
  - Repeatability requirement is ± 18 microns.

Technical Issues & Difficulties - Azimuth

- Repeatability at slew velocities has not been characterized.
- Head alignment can be tricky and time-consuming
- The MCP occasionally receives multiple pulses from a single fiducial crossing. Appears to be caused by electrical noise generated from the windbaffle AC servo amps.
- Head-to-tape spacing is sensitive (± 0.2 mm). We have seen instances of fiducials "disappearing" due to changing temperature conditions.

Azimuth Fiducial System



Fiducial Performance - Altitude

- Insert altitude fiducial performance graphs here…

Technical Difficulties - Altitude

- Repeatability appears to be good, but there is a ratcheting effect that must be understood. Cannot quantify altitude performance yet.
- Ratcheting may be caused by encoder wheel “crabbing” on altitude drive disk.
- Altitude drive disk position must be stabilized, encoder alignment verified, and altitude fiducial measurements repeated.
- Sensitivity of head-to-tape gap is concern given postion instability of altitude drive disk.

Fiducial Performance - Rotator

- Have not collected and analyzed rotator tape fiducial crossing data in detail.
- Since these fiducials are incorporated directly into the rotator tape encoder system, performance is expected to be equivalent to Heidenhain specifications.
- Anecdotal evidence from performance on the sky suggests that the rotator tape fiducial system is working well.

Rotator Tape Performance

- Made several 360-degree rotation tests in March
- Ideal = (76,000 ticks) x (4 edges) x (400) = 121,600,000 cts/rev
- Measured results:
  - #1: 121,599,884 cts (d = 116 cts) *by hand*
  - #2: 121,599,896 cts (d = 104 cts) *by hand*
  - #3: 121,600,024 cts (d = 24 cts) *using MCP*

Technical Difficulties - Rotator

- Technical difficulties with respect to the rotator servo loop that must be worked out. These may affect the fiducial system if the tape system is eliminated.
- Until further characterization of rotator fiducial repeatability is done, no conclusive statements can be made regarding technical difficulties or issues.
- Potential technical issues include alignment stability over time, performance at different velocities and temperatures, etc.

Possible Changes and Refinements

- Improved head alignment system (seasonal adjustments may be needed)
- Improved head holder to accommodate thermal expansion effects.
- Modified interface circuitry to eliminate multiple interrupts and address noise sensitivity.

Reliability and Serviceability

- Long term temperature effects on head spacing are a concern.
- Tape surface is robust. Should not see performance loss due to tape deterioration.
  - Periodic cleaning with ethyl alcohol is recommended to maintain tape surface cleanliness.
- Effects of temperature and altitude on electronics is questionable, but early experience at APO and other observatories suggest this should not be a problem.
- All parts are easily accessible, and spares exist on site for all components.

Failure Modes

Safety Issues

- There are no significant personnel safety issues associated with the telescope fiducial system.
  - The head-to-gap spacing is very small and it would be possible to get a finger caught between a tape block and head. However, the likelihood of this is remote and does not warrant the fabrication of guards.

- If the fiducial system stops working, the telescope coordinate system cannot be initialized and the telescope may lose track of where it is. This affects operations, but should not compromise personnel or equipment safety. The interlock system will prevent improper motion that would damage the telescope.

Documentation Status

- Documents exists for the various components that comprise the telescope fiducial system, but this information has not been assembled into manuals suitable for telescope operations.

- Documentation is piece-meal at this point.

Plans for Completion

- Prior to September 1999 Dark Run
  - Develop baseline measurements to characterize performance at different velocities and over time.
  - Collect and analyze performance data on all axes to characterize and baseline performance.
  - Assemble documentation booklets for each fiducial system (az, alt, and rotator)

Plans for Completion

- Through the Fall 1999 Commissioning Period
  - Collect performance data over time and under different temperature conditions to begin developing a performance history.
  - Address issues as they arise.
- Help is needed to complete these tasks.

Summary

- Fiducial system is installed and functional on all three axes.
- More testing must be done to quantify performance over time and under varying system conditions (temperature, velocity).
- Altitude drive problems must be resolved before altitude fiducial performance can be quantified.
- Areas of concern include alignment stability, repeatability over time, and generation of multiple interrupts due to electrical noise.
- System documentation must be completed.